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Investigation of *Salmonella* Content of Powdered Whole Egg With Not More Than Two Percent Moisture Content. IV. Bactericidal Action of the Preheater on *Salmonella* in Liquid Whole Egg

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The use of the preheater for minimizing the potential health hazard due to *Salmonella* in commercially processed spray-dried, low-moisture, whole egg powder is clearly demonstrated in this study.

Commercial liquid whole egg is generally known to have high viable bacterial loads and has been considered a potential vehicle for wide dissemination of pathogenic bacteria such as *Salmonella*. In the manufacture of spray-dried whole egg powder, the presence of these bacteria in the product is undesirable. Liquid whole egg produced from chicken eggs under laboratory conditions has rarely been found to be contaminated with *Salmonella*, according to Cantor and McFarlane (2) and Chase and Wright (3). The latter workers examined a large number of eggs and isolated only *S. pullorum*, a species native to fowls. Solowey, Spaulding and Goresline (8) have expressed the opinion that the external egg shell surface is an important source of contamination with *Salmonella*, unknowingly introduced into liquid whole egg by egg-breaking personnel.

At the time of this study the specification (5) for procurement of low-moisture, whole egg powder for the Armed Forces included a requirement for the use of a preheater in the processing of whole egg powder. While the preheater was primarily intended for lowering the moisture content in the egg product, it also had the important function of bacterial destruction. The author (6, 7) has presented strong evidence which associates the preheater with significant reduction of the incidence of *Salmonella* in spray-dried, low-moisture, whole egg powder. Pasteurization of liquid whole egg is an effective means of destroying *Salmonella* in this product, according to Winter, et al. (10, 11). Solowey, Sutton, and Calesnick (9) reported a heat-resistance study of 24 *Salmonella* types isolated from egg powder; they express the opinion that flash pasteurization at 60° C. of liquid whole egg would markedly reduce the number of *Salmonella* organisms in the egg powder.

This study is a detailed account of an earlier work by the author on the function of the preheater in destroying *Salmonella* in heated commercial liquid whole egg which minimizes the potential health hazard from these

bacteria in the processed egg powder. The data include information on total viable bacterial loads of the liquid as well as the spray-dried whole egg.

Between February, 1945 and July, 1945 a uniform system of Veterinary Corps Inspection Service afforded an opportunity to examine microbiologically a random series of egg pulp samples procured for Army "Backlog"^b [de Tienne, (4)]. The incidence of *Salmonella* is noted in this product.

Limited observations are recorded on the occurrence of *Salmonella* in high-moisture (5%) whole egg powder procured under Army Veterinary inspection during 1945.

EXPERIMENTAL PROCEDURE

Processing technology of three commercial egg dehydrating establishments were studied extensively. Six daily production runs of whole egg powder, including the raw, flash heated [60.5-61.8° C. (141-143° F.)] and pasteurized liquid egg were examined qualitatively for the presence of *Salmonella* organisms. Defrosted whole egg and fresh-broken out whole egg (from spring-produced current receipts) served as the source materials for the experiments herein reported. Liquid and spray-dried whole egg were collected at hourly intervals during full day production runs. Experiments conducted in plant A are noteworthy because two Rogers-type spray driers were being operated in parallel. The preheater to one of the driers was shut down. It was thus possible to dry one source of defrosted whole eggs under two conditions simultaneously, namely, with and without the processing aid of the preheater. In plants B and C egg processing operations were carried out with and without assistance of the preheater on each of two consecutive days. Defrosted whole egg was the source material for the commercial production run in plant B, while fresh liquid whole egg from spring-produced current receipts were employed in plant C.

The procedure used for isolation and identification of *Salmonella* organisms has already been reported by the author (6, 7). Standard plate counts of viable bacteria were determined as previously described (7).

RESULTS

During the microbiological examination of the 1945 frozen egg "Backlog," 199 samples of egg pulp were examined for the presence of *Salmonella* organisms. An incidence of 30.7% was found. Of 61 isolations, 60 cultures were *S. pullorum* and one culture was *S. oranienburg*.

^b "Backlog," a term used by de Tienne, refers to high quality frozen eggs procured for production of egg powder for military needs. She has presented evidence that effective sanitary measures during production and processing of frozen whole eggs will result in relatively low viable bacterial counts of manufactured egg powder.

^a This work was done while the author served as Captain, Veterinary Corps, U. S. Army, at the Seventh Service Command Medical Laboratory, Fort Omaha, Omaha, Nebraska. The views or conclusions contained in this report are those of the author. They are not to be construed as necessarily reflecting the views or indorsement of the Department of Defense.

Sixty-three lots of high-moisture whole egg powder (containing about 5% moisture) showed an incidence of *Salmonella* organisms of 9.5%. Six cultures of *Salmonella* were identified and included *S. typhi-murium*, *S. montevideo*, *S. paratyphi B*, *S. cerro*, and two cultures of *S. oranienburg*.

Under conventional operating conditions in plants A and B using Rogers-type spray driers, the preheater is definitely effective in reducing the *Salmonella* incidence in spray-dried whole egg powder. Even with apparently heavy contamination of the defrosted raw whole egg liquid, the preheater was the site of *Salmonella* destruction. Results are summarized in Tables 1, 2, and 4. The first of two experiments in plant C, using a Douthitt-type drier, were conducted during the season of spring egg receipts. Here *S. pullorum* was recovered from low-moisture whole egg powder processed without the assistance of the preheater (Table 5). On the second day of the test, the liquid whole egg was preheated, and in addition, held for 6 minutes at 60.5-61.8° C. (141-143° F.). No *Salmonella* were found in fourteen samples of egg powder obtained from spray-drying the pasteurized liquid egg.

The survey of spring egg receipts and observations on the unheated whole egg liquid used for spray-drying during the same spring season (Tables 3 and 5) revealed *S. pullorum* as the principal contaminant of the liquid egg mix. On the other hand, during November and December, 1944, unheated defrosted liquid eggs in plants A and B were heavily contaminated with a variety of *Salmonella* types other than and including *S. pullorum*.

Based on standard plate counts of viable bacteria in egg during two consecutive production runs at plant C, commercial practices of preheating and short-time pasteurization of liquid whole egg made the isolation of *Salmonella* a difficult task, and permitted survival of relatively insignificant numbers of viable microorganisms.

DISCUSSION

Extensive microbiological research from several laboratories has established unequivocally that commercial produced liquid whole egg and dried whole egg powder constitute important vehicles for wide dissemination of *Salmonella* organisms. For this reason egg and egg products provide a method for increasing *Salmonella* carrier rates among handlers of these products who are considered the usual source of human salmonellosis in the United States (1). Thus, a situation has been created which, in the author's opinion, indirectly favors potential egg-borne salmonellosis in man.

The interesting work of de Tienne (4) surveying commercial practices in certain egg-breaking plants has revealed the lack of efficient sanitary practices during egg-breaking operations. It is not surprising, therefore, that bacteriological investigations have revealed external egg shell surfaces to be one factor in the contamination of liquid eggs with *Salmonella* types. Personnel unwittingly introduce *Salmonella* organisms into egg meats during the breaking-out of eggs which have been inadequately cleaned of fecal contamination of poultry origin.

The bacteriological work herein presented had been carried out on high quality egg and egg products. Furthermore, it should be pointed out that commercial processing of this high quality whole egg powder was constantly supervised by an extensive veterinary inspection service. The type of data reported, therefore, are in fact a reflection of the best existing commercial practices in the manufacture of egg powder at the time of these tests.

Production of low-moisture (2%) whole egg powder does not imply the exclusion of *Salmonella* organisms from this product even though processed from a superior-type raw material. It is only when the liquid egg has been preheated to a minimum of 60° C. (140° F.) prior to spray-drying that *Salmonella* organisms have been so reduced in numbers as to make their isolation in egg powder a rarity. Preheating and

TABLE 1
Survival of *Salmonella* in commercial spray-dried, low-moisture, whole egg powder. Plant A, Twin Rogers-Type Driers *

Liquid whole egg, unheated			Low-moisture whole egg powder processed without aid of preheater			Low-moisture whole egg powder processed with aid of preheater (flash to 140-141° F.)		
Hour of operation	SPC ^c per gram	<i>Salmonella</i> isolated	Hour of operation	SPC ^c per gram	<i>Salmonella</i> isolated	Hour of operation	SPC ^c per gram	<i>Salmonella</i> isolated
1	880,000	<i>S. oranienburg</i>	1	105,000	.....	1	8,600	<i>S. tennessee</i>
2	880,000	.....^d	2	85,000	.....	2	10,600	.....
3	640,000	.....^e	3	152,000	<i>S. oranienburg</i>	3	11,700	.....
Liquid whole egg, preheated (flash to 140-141° F.)			4	9,800	<i>S. oranienburg</i>	4	10,400	.....
1	660,000	.....	5	12,000	.....	5	4,000	.....
2	30,000	.....	6	14,800	.....	6	4,400	.....
3	30,000	.....	7	15,300	<i>S. oranienburg</i>	7	5,200	.....
			8	11,900	.....	8	4,000	.....
			9	13,900	.....	9	4,000	.....
			10	8,400	.....	10	7,600	.....
			11	9,900	.....	11	11,800	.....
			12	11,000	.....	12	21,000	.....
			13	4,700	.....	13	22,800	.....
			14	11,300	.....	14	74,000	.....
			15	16,400	.....	15	24,500	.....
			16	12,500	.....	16	21,000	.....
			17	37,000	.....	17	66,000	.....
			18	44,000	.....	18	78,000	.....
			19	10,200	.....	19	70,000	.....
			20	7,600	.....	20	50,000	.....

^c SPC is standard plate count.

^d *Salmonella* organisms not detected.

^e Driers operating simultaneously, November 15, 1944.

TABLE 2

Survival of *Salmonella* in commercial spray-dried, low-moisture, whole egg powder. Plant A, Twin Rogers-Type Driers *

Liquid whole egg, unheated			Low-moisture whole egg powder processed without aid of preheater			Low-moisture whole egg powder processed with aid of preheater (flash to 140-141° F.)		
Hour of operation	SPC # per gram	<i>Salmonella</i> isolated	Hour of operation	SPC # per gram	<i>Salmonella</i> isolated	Hour of operation	SPC # per gram	<i>Salmonella</i> isolated
1	44,000	<i>S. tennessee</i>	1	30,400	<i>S. pullorum</i>	1	40,000	.....
2	104,000	<i>S. oranienburg</i>	2	12,000	.....	2	32,000	.....
		<i>S. pullorum</i>	3	36,000	.....	3	10,400	.....
		<i>S. tennessee</i>	4	29,600	.....	4	44,000	.....
5	156,000	<i>S. oranienburg</i>	5	45,000	.....	5	67,000	.....
6	60,000	<i>S. tennessee</i>	6	20,800	.....	6	40,000	.....
21	1,320,000	.....	7	25,000	.....	7	54,000	.....
Liquid whole egg, preheated (flash to 140-141° F.)			8	20,800	<i>S. pullorum</i>	8	76,000	.....
1	8,000	.....	9	80,000	.....	9	.....	.....
2	20,000	.....	10	33,000	<i>S. pullorum</i>	10	32,400	.....
6	12,000	.....	11	30,400	.....	11	31,200	.....
21	410,000	.....	12	17,600	.....	12	40,000	.....
			13	72,000	<i>S. pullorum</i>	13	104,000	.....
			14	72,000	.....	14	70,000	.....
			15	196,000	<i>S. pullorum</i>	15	100,000	.....
			16	142,000	<i>S. pullorum</i>	16	80,000	.....
			17	410,000	<i>S. pullorum</i>	17	112,000	.....
			18	160,000	<i>S. pullorum</i>	18	120,000	.....
			19	141,000	<i>S. pullorum</i>	19	200,000	.....
			20	260,000	<i>S. pullorum</i>	20	182,000	.....
			21	1,040,000	<i>S. pullorum</i>	21	600,000	.....

* Driers operating simultaneously, November 25, 1944.

Standard plate count.

TABLE 3

Effect of the preheater on the survival of *Salmonella* organisms found naturally in commercial liquid whole egg. Plant A ^b

	Hour of operation	Temperature of egg pulp ° F.	SPC ¹ per gram	<i>Salmonella</i> isolated
Liquid whole egg, unheated	1	.....	172,000	.....
	4	.....	89,000	<i>S. pullorum</i>
	8	.....	95,000	<i>S. pullorum</i>
	12	.....	116,000	.....
	16	.....	288,000	.....
Liquid whole egg, preheated (flash)	1	140	5,800	.....
	2	141	4,700	.....
	3	140	7,900	.....
	4	140	< 3,000	.....
	5	141	4,200	.....
	6	140	6,600	.....
	7	140	12,000	.....
	8	140	15,000	.....
	9	.....	62,000	.....
	10	140	18,000	.....
	11	141	18,000	.....
	12	140	45,000	.....
	13	140	22,000	.....
	14	140	15,000	.....
	15	140	12,000	.....
	16	140	80,000	.....
	17	140	44,000	.....
	18	140	47,000	.....
	19	140	53,000	.....

^b February 15, 1945.¹ Standard plate count.

providing a 2-5 minute pasteurization of liquid egg at not less than 60° C. (140° F.) will in the author's opinion, completely exclude *Salmonella* organisms from manufactured whole egg powder.

It is concluded that technological methods for processing egg powder are available for the total exclusion of *Salmonella* organisms from whole egg powder.

SUMMARY

1. Liquid whole egg produced from spring-produced (1945), current receipts show a high incidence of contamination with *S. pullorum*.

2. Frozen whole egg used for autumn-winter (1944-1945) spray-drying were also found to be contaminated with several *Salmonella* types, including *S. pullorum*.

TABLE 4

Survival of *Salmonella* in commercial spray-dried, low-moisture, whole egg powder. Plant B, Rogers-Type Drier.

Liquid whole egg, unheated ¹			Liquid whole egg, unheated *		
Hour of operation	SPC ¹ per gram	<i>Salmonella</i> isolated	Hour of operation	SPC ¹ per gram	<i>Salmonella</i> isolated
1	53,000	<i>S. oranienburg</i>	1	86,000	<i>S. pullorum</i>
4	63,000	<i>S. oranienburg</i>	4	55,000	<i>S. pullorum</i>
8	63,000	<i>S. oranienburg</i>	8	30,000	.....
12	52,000	<i>S. oranienburg</i>	12	< 30,000	<i>S. oranienburg</i>
16	68,000	<i>S. oranienburg</i>	16	< 30,000	<i>S. oranienburg</i>
Low-moisture whole egg powder processed without aid of preheater ¹			Liquid whole egg, preheated (flash to 141-143° F.) ^k		
4	27,300	<i>S. pullorum</i>	1	< 30,000	.....
5	20,400	<i>S. oranienburg</i>	4	< 30,000	.....
6	16,600	<i>S. pullorum</i>	8	< 30,000	.....
7	20,000	.....	12	< 30,000	.....
8	12,000	<i>S. pullorum</i>	16	< 30,000	.....
9	14,000	.....	Low-moisture whole egg powder processed with aid of preheater (flash to 141-143° F.) ^k		
10	17,900	.....	2	7,000	.....
11	14,600	<i>S. pullorum</i>	3	9,200	.....
12	22,600	<i>S. pullorum</i>	4	8,000	.....
13	15,600	<i>S. oranienburg</i>	5	8,400	.....
14	14,200	<i>S. oranienburg</i>	6	7,400	.....
15	11,400	<i>S. pullorum</i>	7	10,000	.....
16	19,600	.....	8	4,800	.....
17	9,800	<i>S. pullorum</i>	9	7,000	.....
			10	6,200	.....
			11	8,700	.....
			12	4,200	.....
			13	5,800	.....
			14	6,600	.....
			15	12,200	.....
			16	5,600	.....
			17	10,400	.....
			18	4,800	.....

¹ 28 December 1944.

* 29 December 1944.

^k Standard plate count.

3. The commercial practice of preheating liquid whole egg (140° F. and above) prior to spray-drying effectively reduces the incidence of *Salmonella* organisms in whole egg powder.

4. Preheating and short-time pasteurization of high quality liquid whole egg at one less than 60.5° C. (140° F.) for 2-5 minutes will entirely eliminate *Salmonella* organisms from processed egg powder.

TABLE 5

Survival of *Salmonella* in commercial spray-dried, low-moisture, whole egg powder. Plant C, Douthitt-Type Drier

Liquid whole egg, unheated ^m			Liquid whole egg, unheated ⁿ		
Hour of operation	SPC ^o per gram	<i>Salmonella</i> isolated	Hour of operation	SPC ^o per gram	<i>Salmonella</i> isolated
1	45,000	<i>S. pullorum</i>	1	76,000	.....
4	88,000	.....	4	74,000	<i>S. pullorum</i>
8	42,000	.....	8	28,000	<i>S. pullorum</i>
12	151,000	.....	12	54,000	.....
Low-moisture whole egg powder processed without aid of preheater ^m			Liquid whole egg, preheated (flash to 141° F.) ⁿ		
1	10,000	.....	1	<3,000	.....
2	4,200	.....	2	4,900	.....
3	440,000	.....	3	6,000	.....
4	9,000	.....	4	6,300	.....
5	780,000	.....	5	4,600	.....
6	9,800	.....	6	5,700	.....
7	4,800	.....	7	5,400	<i>S. pullorum</i>
8	12,100	.....	8	7,800	.....
9	5,500	.....	9	<3,000	.....
10	4,700	<i>S. pullorum</i>	10	5,500	.....
11	8,000	<i>S. pullorum</i>	11	5,700	.....
12	10,300	.....	12	5,400	.....
			13	<3,000	.....
			14	4,300	.....
Pasteurization, holding vat 141-143° F., 6 minutes ⁿ					
1	<3,000	.....		
2	<3,000	.....		
3	<3,000	.....		
4	5,000	.....		
5	10,000	.....		
6	4,100	.....		
7	<3,000	.....		
8	<3,000	.....		
9	<4,000	.....		
10	<3,000	.....		
11	<3,000	.....		
12	3,700	.....		
13	<3,000	.....		
14	<3,000	.....		
Low-moisture whole egg powder processed from pasteurized egg ⁿ					
1	<3,000	.....		
2	27,500	.....		
3	<3,000	.....		
4	<3,000	.....		
5	<3,000	.....		
6	<3,000	.....		
7	<3,000	.....		
8	<3,000	.....		
9	<3,000	.....		
10	4,200	.....		
11	4,800	.....		
12	3,400	.....		
13	5,700	.....		
14	5,000	.....		

^m March 1, 1945.

ⁿ March 2, 1945.

^o Standard plate count.

5. Examination of 63 lots of high-moisture (5%) whole egg powder revealed a 9.5% incidence of *Salmonella* organisms of the following types: *S. typhimurium*, *S. montevideo*, *S. paratyphi B*, *S. cerro* and *S. oranienburg*.

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